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ABSTRACT

The use of computer-produced materials remote from the terminal can revitalize teaching devices and techniques such as graded exercises, precision teaching, and even conventional text. Teachers need to be aware of inconsistencies in the quality of computer software and of logistical factors involved in the adoption of computer assisted instruction (CAI) in their schools. Six criteria that are relevant to learning in general against which the validity of a given program of CAI might be judged are (1) the law of frequency, (2) motivation, (3) multisensory stimulation, (4) attention, (5) learning by doing, and (6) analysis of learning task into concurrent components and prerequisite antecedents. Practice exercises in spelling and in basic arithmetic are good examples of computer-generated material. Such pedagogically sound teaching material can result from cooperative communication between good, competent, and articulate teachers on the one hand and good, competent, and understanding programers on the other. (An extensive appendix includes figures that depict part of a computer produced diagnostic test, a computer version of an exercise in basic arithmetic, and a computer printout that illustrates the concepts of product-moment correlation and regression.) (AEA)

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A CLASSROOM TEACHER'S AIDE:

THE COMPUTER AS A GENERATOR OF MATERIALS

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
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by

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Vancouver, B.C., February 1980

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In the face of the overwhelming, and maybe sometimes overweening, self-confidence, of proponents of computer-aided instruction, two equally disturbing reactions are likely from many teachers.

Some will hope -- vainly, of course, that CAI will go away, or at least will not affect them to any significant degree. Then, there will be those who will recognize, or at least dimly sense the inevitability of events, but feel helpless and even hopeless, rather like someone trying to carry on building their sand castle as the tide comes inexorably in. I think it would be fair to say that I am conservative by nature, but no Canute.

My general thesis is that educators -- and by educators I mean teachers -- should embrace CAI enthusiastically, but with two cautions:

(1) quality of software, and

(2) logistical factors.

Quality of software

We must recognize that technological sophistication and elegance do not in themselves guarantee educational sophistication, nor even educational relevance. Or, put another way, we must distinguish between quality of hardware and quality of software. There is more than a possibility that -- until the computer becomes as commonplace in schools as books -- that credulous (and frequently innumerate) teachers might be so overawed by the impressive hardware with which they have suddenly been confronted that they will take it for granted that the accompanying software is of comparable

educational and psychological quality; a sort of validation by association. Of course, scepticism about software must be healthy, constructive scepticism, and it is clear that the development of CAI will, in all probability, force us to amend some previously held principles about factors which facilitate or impede learning, because of the potential which computer-based instruction offers for the designing of more tightly-controlled experimental procedures. But, for the time being, we do have an accumulated body of psycho-educational knowledge from which to begin.

Logistical factors

Consideration has also to be given to the specific circumstances in which CAI is used in a school situation. That is, some attention must be paid to logistical factors in the adoption of CAI in schools. Even given the reducing costs and increasing availability of microcomputers, how is this individualized equipment going to be used in a school teaching situation even if there is one computer per class (and for a little while, only Alberta will be able to aspire to this)? If the computer were in use for every minute of the school day, each student in a class of 30 would have face-to-face access for only 50 minutes per week. It seems we have to buy more computers, restrict their use to those students for whom the benefits or needs are greatest, use them out of school hours -- or find alternative modes of computer use in addition to the usual individual interface situation.

It is to this last alternative that I submit more time and attention might profitably be directed. We have heard at this conference how the price of computers has been tumbling at such a rate that it seems we should be able to look forward shortly to the day when manufacturers will be paying us to

take a computer. Indeed, it seems that if you buy a computer from some companies, they will give you a second one free -- a sort of one cent sale. I have even heard that it might be possible to be given the hardware upon promising to buy associated software. Maybe it is my Scottish genes that compel me to feel that free hardware for a promise to buy software might be rather like being offered an apartment in downtown Vancouver rent-free, with an annual charge of $10,000 for the key.

Criteria of educational relevance and validity

Returning to the quality of software, let us consider in a little more detail some of the criteria against which the educational relevance and validity of a given program of CAI might be judged. There is an obligation on those of us who have been engaged in the horse-and-buggy form of teaching, to identify -- or rather, to remind ourselves -- of some of the facts, principles and effective teaching techniques which have been established through experience and experiment, and to ask whether these can be adopted, adapted, expanded, improved -- or even replaced -- with the help of the computer software.

I have been playing with computers -- essentially as a hobbyist -- since around 1962 and largely within a context defined by my academic and professional interests and needs, which have been the education of exceptional children, particularly children with learning disabilities; and with teaching elementary statistics and research methods to graduate education students. So the comments I shall be making should be set against this background.

Six ingredients that are relevant to learning in general, but relevant in particular to children with learning disabilities, are:

(1) The law of frequency

(2) Motivation

(3) Multisensory stimulation

(4) Attention

(5) Learning by doing

(6) Analysis of learning task

(a) concurrent components

(b) prerequisite antecedents.

The law of frequency

Educators have traditionally stressed learning by insight; for example, reading for meaning rather than rote learning. Certainly, a truly educated person is one who has insight, who does not simply regurgitate undigested facts. But don't knock drill. One of the more firmly established findings about children with learning disabilities is that they tend to have weaknesses, or deficiencies, in communication skills that are learned more-or-less automatically and incidentally by other children. That is, learning disabled children tend to have difficulty with syntax rather than with semantics; with remembering the days of the week in sequence; in perceiving the difference between the phonemes associated with the letters m and n; with short-term rote memory. Unfortunately, these skills, which have to be remediated, are not skills that can be taught by insight, but by repetitive drill, which can be deadly dull and therefore deadly difficult to teach.

Motivation

This is where the second ingredient comes in, motivation. At present, computer-based activities (even such T-model activities as the Merlin toy) have a novelty value. The computer affords an opportunity to dress up time-honoured (and in some cases, time-proven) methods in a more attractive garb. For example, spelling has been traditionally taught by having children learn the orthographic representations of sets of spoken words as paired associates, and by having children write out (say) five times, each spelling mistake and -- if the exercise were seen as remedial rather than as punitive -- the child would call out the name of each letter as he wrote it, and the name of the whole word when completed. This can be terribly boring, particularly for the child who makes lots of mistakes and who therefore needs lots of help. The same remedial exercise, when presented via a computer, can become far more attractive and therefore more motivating.

A program we have been using for years and which is popular with children essentially replicates the old-fashioned spelling method. A week's quota of daily lists to be learned is set up. A child has to copy (from memory) a word that has been presented briefly. If he does this correctly, the next word is presented; if an error is made, the word is repeated and then progressively the stimulus is reduced (one or more letters at a time, at random) till the child is responding to a zero stimulus. Essentially, the child is "copying out the word five times". Visual/auditory association occurs because the student has to call out each letter as it is typed, and the word itself is said as the return button is pressed. One formal experiment showed that a sample of severely retarded spellers made about

six months progress in spelling in six weeks. Unfortunately -- in a sense -- the control group who had been doing arithmetic items on the computer for six weeks, made about five months progress -- in spelling. (Robertson, 1973).

The element of novelty, or gimmick-value of the computer is, probably temporarily of value in increasing motivation and attention.

As already mentioned, incidental learning cannot be assumed with learning disabled students. Hence, although it may be true -- but I'm not convinced -- that the "game" element of many computer programs can be of assistance, especially in introducing the student to the computer, don't expect that a desired skill will automatically be learned as a by-product of playing some game.

A far more effective motivational factor is self-competition. Many years ago now, my late boss, Sir Fred Schonell designed some excellent, effective exercises to train or remediate skills in basic arithmetical processes. Students had to work through a series of exercises, linked to diagnosed weaknesses, in a fixed time limit. They monitored their own success rate and recorded their (often spectacular progress) on a graph. More recently, the same sort of thing has re-emerged as "Precision Teaching" and I have transferred Schonell's old effective idea to the computer mode, with a few improvements that I will come back to later.

Multisensory stimulation

The value of multisensory stimulation has been long recognized, at least since Anne Sullivan taught Helen Keller. Reference was made earlier to the

spelling program in which the student is required to associate visual symbol with auditory linguistic sound (and at the same time is encouraged to listen to himself -- the process of reauditorization being another skill where many learning disabled children have a problem). But stimulation of different senses must be as near as possible totally redundant, especially for learning disabled students. That is, there must be a one-to-one correspondence between what is sensed by the eye and the ear. Having to attend to messages from different modalities that are not highly correlated, is likely to overload a child's communication channel beyond its capacity.

Attention

A frequently cited symptom of learning disability is distractibility, or short attention span; the consequence for designing remedial procedures has been to highlight the stimulus, keep tasks relatively short and to reduce the stimulus strength of environmental distractions. In an individual interface situation, the computer clearly has intrinsic characteristics that lend themselves ideally to taking care of necessary attentional factors.

Learning by doing

It is an old but valid educational cliché that children (or anyone else, for that matter) learn best by doing. The advent of the computer has been a mixed blessing as far as this criterion is concerned.

In current jargon, "interfacing" with a computer terminal seems -- particularly to the uninitiated -- to be "where the action is". We need to remind ourselves that working on the receiving end of a computer program can be, and often is, an extremely passive occupation, and one in which the

puppet of the programmer. In the past couple of years or so, I have refocussed a good deal of my professional attention to the area of special education where I first began 35 years ago, i.e. the education of gifted students. One of the attributes of gifted students, and other students for that matter, and one which would benefit from being strengthened, is their capacity to think creatively, an attribute that is far too frequently equated with "creativity", i.e. what "tests of creativity" purport to measure.

I have read several suggestions as to how students can be helped to improve their creative thinking skills by means of the computer, usually by playing games, but have had both first- and second-hand experience of children identified as gifted getting really hooked on to computer games, but being extremely reluctant to progress to active involvement with programming. Yet writing a computer program incorporates the basic condition of divergent productive thinking in that there is no one pre-ordained solution, and there is immediate feedback and checks of the validity of the progress of the problem solving process.

Another of the arguably negative impacts of the computer in reducing "learning by doing" is observable at the graduate student level -- at least in Education and, I suspect, the social sciences generally where, to paraphrase what Launcelot Hogben once said in another context, statistical output from the computer is accepted as critically and "in a temper as likely to encourage a rational scepticism as did the forced repetition of the lesser catechism to Scottish children of an earlier generation".

What I am saying is that the computer can be valuable as a vehicle for learning by doing. But it should not be taken for granted that by simply sitting at a keyboard and pressing response keys, one is necessarily doing anything in a meaningfully active sense. Indeed it could be just the opposite.

Analysis of learning task

In any learning situation, but particularly for students who have been experiencing difficulties, learning tasks need to be carefully graded. To develop a hierarchy of sequential learning targets calls for task analysis. A task which is demonstrably presenting difficulties calls for analysis into concurrent constituent elements of the task presented. This is an operation for which a person with competences in computer programming should be excellently equipped. But, it is also necessary to analyze the present task in terms of prerequisite antecedent skills. For this part of the analysis, some psycho-educational diagnostic competences are necessary; that is, some knowledge of developmental ordering of elements that make for difficulty in a given task.

For example, Figure 1 depicts part of a diagnostic test that we use in identifying where an elementary school student might be going wrong in one of the basic arithmetic processes.

Some examples of computer generated materials

A sample of illustrative examples from the programs that have been in use at the Institute for several years are presented below. The first is for teaching at the remedial (elementary) level and the others are from a set of

programs designed to illustrate elementary statistical concepts.

There are also individualized programs at the remedial level, but the one illustrated below does not involve the student sitting at the console. Rather, the computer program generates exercises, prints them on paper and the students complete the exercises as a conventional paper and pencil task. This arrangement means that the computer can be working when classes are not in session, and can produce materials for many students to use simultaneously as and when required.

Practice in basic (graded) arithmetic

Reference was made earlier to the very successful remedial arithmetic books produced back in the pre-ditto days, let alone the pre-computer days, by Schonell. The exercises in these books required the child to go over the same exercise (in a graded series of exercises) to keep a record of her/his performance and, on subsequent repetitions of the exercise, to try to beat her/his previous performance. This simple, but highly motivating experience effectively sugared the pill of repetitious learning. Two further pedagogically excellent characteristics of Schonell's exercises were that the child did not waste time copying the item (tracing paper was placed over each exercise) and the child was able to check her/his performance -- and get non-threatening immediate feedback -- because the answers were at the back of the book. One drawback of Schonell's exercises is that they are necessarily constant so that, after two or three exposures to a particular exercise, a child can recall the initial sequence of answers without having to address the specific item itself.

Figure 2 illustrates the computer version of the Schonell-type exercise, geared to defined specific difficulties shown up by the diagnostic test previously illustrated, but the items in each exercise are in randomized or semi-randomized order. As with the Schonell exercise, answers are available for self-monitoring.

Figure 3 reproduces the computer printout designed to illustrate the concepts of product-moment correlation and regression. The student is able to call forth correlations of different magnitudes and get a "feel" for what a particular correlation coefficient signifies. By calling forth the histograms representing the distribution of scores in any specified row or column, s/he is reminded of the ubiquitous presence of the normal curve of distribution and the equally inevitable, but generally little understood, phenomenon of regression toward the mean.

Concluding remarks

I have not been trying to impress you with some home-grown programs. Rather, I am suggesting that some teaching devices and techniques such as graded exercises, precision teaching and even conventional text can be re-vitalized through the dynamic dimension which the computer makes possible (and, incidentally, increase the ratio of benefits to cost) by producing conventional teaching materials which can be used remote from the terminal.

Who has the competences to produce pedagogically-sound teaching materials? Occasionally, one gets a feeling that some CAI zealots would prefer that common teachers become not too involved but, like a conforming laity, leave the interpretation and development of the revealed mysteries of CAI to a

newly emerging priesthood.

I have been to too many one-day computer workshops where verbally intelligent educators have enthusiastically followed the instructor until the mid-morning coffee break, and then become progressively and visibly befuddled. And there has always been a noticeable thinning out in the ranks for the afternoon session.

Conversely, I have called up allegedly academic games from the computer library and found them to be quite inferior to the exercise which most self-respecting Grade 3 teachers could and would put on the blackboard. If the silicone revolution in the schools is not to degenerate into an endless loop of Battleships, Masterminds and Stock Exchange games, or worse -- to consist of ambitious programs monopolized by people who know a lot about mathematics and complex programming, but precious little about children (remember New Math!), it is essential that there be co-operative communication between good, competent and articulate teachers on the one hand, and good, competent and understanding programmers, or instructional technologists, on the other.

Good teachers have to be encouraged to develop the competency of presenting their needs in terms which are compatible with what CAI has to offer, that is to be taught the dimensions of the task analysis. Good programmers, for their part, have to be made aware of something of the principles of effective diagnostic teaching procedures.

In other words, we have to move, as Charles Osgood once put it, in a different context, "toward a wedding of insufficiencies".

APPENDIX

FIGURE 1

GRADED ADDITION

4 1 + 4	2 3 + 3	1 6 + 2	3 digits, sum less than 10
5 1 + 5	6 2 + 7	3 4 + 5	3 single digits, sum of first two less than 10.
2 +16	15 + 4	3 +11	1 - digit plus 2 - digit; no carrying.
46 +11	14 +35	13 +33	2 - digit plus 2 - digit; no carrying.
12 + 8	26 + 6	7 +44	Higher decade bridging.
312 +486	174 +315	222 +563	3 - digit numbers; no carrying.
35 +40	20 +17	41 10 +38	2 - digit numbers. Zero in units. No carrying.
14 +37	59 +36	82 +28	2 - digit numbers. Carrying 1 in units.
23 49 +19	38 27 +45	56 19 67 +38	2 - digit numbers. Carrying 2 or more in units.
37 10 +23	23 17 +40	50 36 +26	Zero in units. Carrying.
431 +287	694 +212	373 +576	3 - digit addends. Carrying in ten's.
396 +225	456 +187	272 +598	3 - digit addends. Carrying in units and ten's.
195 +216	416 +364	343 +565	3 - digit addends. Mixed carrying.
15 603 9 +473	806 197 20 + 9	358 76 27 +419	Numbers of unequal length. Zeroes, carrying.

GRADED SUBTRACTION

15 - 1	13 - 2	18 - 4	Units from tens and units; no borrowing. All numbers less than 20.
36 - 4	74 - 2	68 - 7	Single-digit numbers from numbers more than 20. No borrowing.
19 -15	16 -11	18 -12	2 - digit numbers from 2 - digit numbers; no borrowing. All numbers less than 20.
45 -12	62 -41	89 -37	2 - digit numbers from 2 - digit numbers greater than 20; no borrowing.
13 - 3	32 - 2	67 -17	1 - digit numbers from 2 - digit numbers. Zero in answers.
725 -414	448 -231	586 - 71	Subtraction from 3 - digit numbers; no borrowing.
52 - 3	41 - 7	84 - 6	1 - digit numbers from 2 - digit numbers; borrowing.
57 -37	66 -26	744 -541	2 - and 3 - digit numbers; zeros in difference.
25 -10	37 -20	88 -40	2 - digit numbers; zero in subtrahends.
74 -35	62 -49	97 -58	2 - digit numbers from 2 - digit numbers; borrowing.
516 -143	738 -251	879 -683	3 - digit numbers; borrowing in ten's.
60 - 7	503 -163	400 -215	Subtraction from numbers with zeros.
951 -347	734 -664	432 -178	3 - digit numbers. One or two borrowings.
352 -106	748 -350	871 -809	3 - digit numbers. Zero in subtrahend; borrowing.
3162 -1547	5021 -2613	6070 -1465	4 - digit numbers; zeros and borrowing.

FIGURE 2

```
set-add

run
ADD

      ****    PROGRAM TO GENERATE SETS OF EXERCISES IN ADDITION    ****

Do you need information ?Yes

This program enables you to prepare up to 50 sets of addition
exercises, from the addition of two 1- or 2-digit numbers, with
no carrying, to the addition of up to five 1- or 2-digit numbers,
with carrying all, some or none of the time.  Each exercise will
be printed on a fresh sheet of paper, and may consist of up to
40 items (in multiples of 5).

After all exercises have been printed out, the program prints
the answers, so that a student may monitor her/his own performance.
The exercises are appropriate for a Precision Teaching type of
remediation.  Provision is made for the recording of the number of
items correct per exercise, and also for the number of incorrect
answers.

How many sets of items ?4

How many items per set (multiples of 5 only)?25
How many addends per item ?3
Speed or power test ?Speed
How many minutes per set of items ?10
Do you want carrying in any of the items ?Yes
Do you want carrying in ALL, or only in SOME of the items?
(Answer 'some' or 'all'.?All
DO NOT PRESS THE return BUTTON AFTER THE NEXT ENTRY
UNTIL YOU HAVE TURNED TO THE TOP OF THE NEXT PAGE.

Press any number to start the program.
?6

 1
Name: ......................................

See how many you can get right in  10   minutes.

      15        3        5       42        6
      25       27       59       26       67
    + 22     + 62     +  9     + 19     + 13
    ---      ---      ---      ---      ---

      13       14       62       18       43
      43       29       13       19       19
    +  5     + 35     + 18     +  2     + 17
    ---      ---      ---      ---      ---

      12       71       29        7       17
      30       15       47       41       54
    + 19     + 48     + 20     +  2     +  4
    ---      ---      ---      ---      ---

      13       20       33       28       35
      23        9        9       14       17
    + 44     + 31     + 15     + 24     + 45
    ---      ---      ---      ---      ---

      17       23       30       19       15
       8        6        9       45        9
    + 43     + 66     + 21     + 18     + 65
    ---      ---      ---      ---      ---

Correct: ..........  Error score: ......  Date: ..........
```

2

Name: .....

See how many you can get right in 10 minutes.

28	7	27	42	6
17	47	21	2	13
+ 17	+ 30	+ 17	+ 8	+ 9
---	---	---	---	---
5	7	23	37	13
61	20	26	23	9
+ 24	+ 9	+ 39	+ 28	+ 14
---	---	---	---	---
49	14	24	29	34
32	50	10	38	15
+ 16	+ 28	+ 18	+ 31	+ 24
---	---	---	---	---
5	15	24	59	14
19	65	23	20	48
+ 18	+ 5	+ 19	+ 12	+ 1
---	---	---	---	---
65	11	55	38	18
12	39	20	21	43
+ 4	+ 13	+ 15	+ 1	+ 22
---	---	---	---	---

Correct: ..... Error score: ..... Date: .....

3

Name: .....

See how many you can get right in 10 minutes.

42	5	9	4	19
11	34	58	18	30
+ 19	+ 3	+ 22	+ 14	+ 38
---	---	---	---	---
36	26	4	33	26
3	55	38	3	45
+ 33	+ 15	+ 33	+ 14	+ 23
---	---	---	---	---
54	30	11	4	49
8	17	67	67	11
+ 31	+ 35	+ 16	+ 12	+ 29
---	---	---	---	---
51	41	13	12	6
8	6	48	9	46
+ 14	+ 49	+ 5	+ 19	+ 28
---	---	---	---	---
28	35	20	34	28
19	8	39	23	2
+ 22	+ 39	+ 24	+ 15	+ 4
---	---	---	---	---

Correct: ..... Error score: ..... Date: .....

4

Name: .....

See how many you can get right in 10 minutes.

57	37	8	41	28
2	11	42	27	39
+ 23	+ 12	+ 44	+ 22	+ 22
---	---	---	---	---
16	6	8	55	16
34	15	63	28	43
+ 45	+ 27	+ 2	+ 1	+ 1
---	---	---	---	---
47	6	10	24	4
9	16	17	56	4
+ 16	+ 36	+ 37	+ 10	+ 59
---	---	---	---	---
36	10	58	42	4
18	69	12	29	63
+ 38	+ 19	+ 12	+ 11	+ 16
---	---	---	---	---
23	41	37	26	13
55	24	39	3	15
+ 13	+ 9	+ 21	+ 31	+ 69
---	---	---	---	---

Correct: ..... Error score: ..... Date: .....

********** ANSWERS **********

1

62	92	73	87	86
61	98	93	39	79
61	94	96	50	75
80	60	57	66	97
68	95	60	82	89

2

62	84	65	52	28
90	36	88	88	36
97	92	52	98	73
42	85	66	91	63
81	63	90	60	83

3

72	42	89	36	87
72	96	75	50	94
93	82	94	83	89
75	96	66	40	80
69	82	83	72	34

4

82	60	94	90	89
95	48	73	84	60
72	58	64	90	67
92	98	82	82	83
91	74	97	60	97

DONE

FIGURE 3

```
RUN
890/07

LIST for information about this program.

STOP


LIST
890/07

100  REM ***   THIS PROGRAM GENERATES A CORRELATIONAL MATRIX, WITH THE
102  REM ***   PRODUCT-MOMENT CORRELATION APPROXIMATING TO THE MAGNITUDE
103  REM ***   REQUESTED.
104  REM ***   REGRESSION EFFECTS FOR PARTICULAR LEVELS OF ONE VARIABLE
105  REM ***   MAY BE DEMONSTRATED ON DEMAND.

STOP


RUN
890/07

LIST for information about this program.

How many in sample ?500
Degree of correlation (to one decimal place)?7.5
```

	X:									
Y	59-	60 69	70 79	80 89	90 99	100 109	110 119	120 129	130 139	140+	:Total
140+							1	2	1		4
130 139						4	3	2	3		12
120 129					4	7	9	5	2		27
110 119			4	2	12	21	28	6	2		75
100 109		1	6	14	37	37	15	10	1		121
90 99		2	8	21	39	34	20	4		1	129
80 89		2	13	26	22	20	3	1			87
70 79		5	4	12	11	2					34
60 69	1	2	2		1	2					8
59-			2	1							3
	1	12	39	76	126	127	79	30	9	1	500

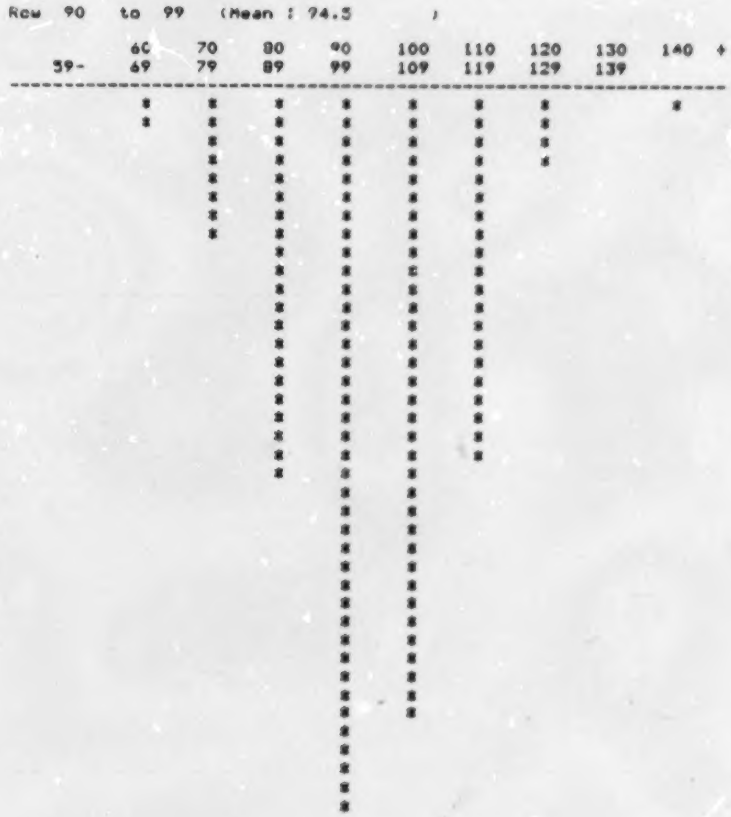
Correlation = .53

s.d. of X = 15.1
s.d. of Y = 15.5

```
How many columns would you like histograms for ?4
What columns are they (Type the lower limit. e.g. if you
want the 100-109 column, type '100' ; for the 59- column,
type '59'
Column #70
Column #90
Column #110
Column #130


Column  70   to  79    (Mean: 74.5        )


 140  +:
 130  +:
 120  +:
 110  +:****
 100  +:******
 90   +:********
 80   +:**************
 70   +:****
 60   +:**
59-   :**

                              Mean =  89.1
                              s.d. =  15.7


Column  90   to  99    (Mean: 94.5        )


 140  +:
 130  +:
 120  +:****
 110  +:************
 100  +:****************************************
 90   +:*******************************************
 80   +:************************
 70   +:************
 60   +:*
59-   :

                              Mean =  96.6
                              s.d. =  12.3


Column  110  to  119   (Mean: 114.5       )


 140  +:*
 130  +:***
 120  +:*********
 110  +:******************************
 100  +:****************
 90   +:*************************
 80   +:***
 70   +:
 60   +:
59-   :

                              Mean =  108.7
                              s.d. =  12.6
```

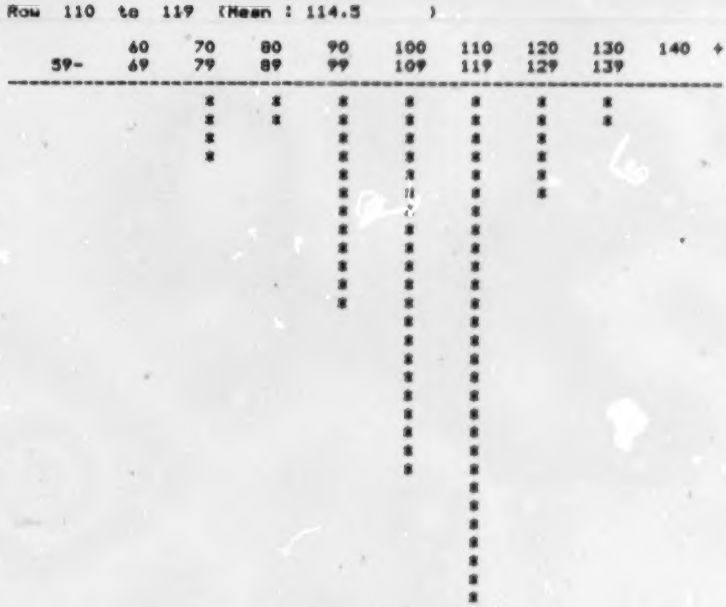
```
Column  130  to  139   (Mean: 134.5       )

 140  +:*
 130  +:***
 120  +:**
 110  +:**
 100  +:*
 90   +:
 80   +:
 70   +:
 60   +:
59-   :

                                Mean =  125.6
                                s.d. =  12

How many rows would you like histograms for ?4
What rows are they? Indicate by typing the lower limit.
If you want the '59-' row, type '59'
Row ?70
Row ?90
Row ?110
Row ?130


Row  70   to  79   (Mean : 74.5       )
          60    70    80    90    100   110   120   130   140  +
    59-   69    79    89    99    109   119   129   139
-----------------------------------------------------------------
           *     *     *     *     *
           *     *     *     *     *
           *     *     *     *
           *     *     *     *
           *           *     *
                       *     *
                       *     *
                       *     *
                       *     *
                       *     *
                       *     *
                       *

                                Mean =  84.8
                                s.d. =  11.2
```

Row 90 to 99 (Mean : 94.5)



Mean = 98.2
s.d. = 13.3

Row 110 to 119 (Mean : 114.5)



Mean = 106.9
s.d. = 12.7

Row 130 to 139 (Mean : 134.5)

	60	70	80	90	100	110	120	130	140	+
59-	69	79	89	99	109	119	129	139		
					*	*	*	*		
					*	*	*	*		
					*	*		*		
					*					

Mean = 117.8
s.d. = 11.8

FIGURE 4

```
LIST
890/04

100  REM: **** THE 890/02 PROGRAM GENERATES UP TO 5 SETS OF SCORES (WITH UP TO
110  REM  15 SCORES PER SAMPLE), ALL WHOLE NUMBERS.  IT THEN PROCEEDS TO
120  REM: DEMONSTRATE HOW DEVIATIONS OF INDIVIDUAL SCORES CAN BE ANALYZED
130  REM: AND ENDS BY DEMONSTRATING THE ADDITIVITY OF VARIANCE.
140  REM'  **** THIS PROGRAM IS THE SAME AS 888/02, WITH THE ADDITION ****
150  REM:       OF THE DERIVATION OF THE F-RATIO FOR A SIMPLE ONE WAY ANALYSIS
155  REM:       OF VARIANCE ****

RUN
890/04

LIST for information about the program.

How many samples (up to 5)?3
How many scores per sample (up to 15)?5


Sample #:
 1     2     3     *            Row mean
*****************************************
 3     3     0     *             2
 1     25    10    *             12
 3     3     0     *             2
 14    8     2     *             8
 4     11    3     *             6
*****************************************
 5     10    3     *             6    (Overall mean)
(Sample means)

    Every individual score may be thought of in terms
of its deviation from the overall mean.  Thus, the
above matrix becomes:

-3    -3    -6
-5     19    4
-3    -3    -6
 8     2    -4
-2     5    -3

    The squares of each of these individual deviations
from the overall mean, are:

          9     9     36
          25    361   16
          9     9     36
          64    4     16
          4     25    9

    The total of these squares, or the 'TOTAL Sum of Squares,
 is  632   ***

    Alternatively, each individual score may be seen as:
        (a) a member of its own particular sample; and
        (b) an individual score within that sample.

    So, therefore , may its deviation from the overall
mean be seen as the sum of:
        (a) the deviation from the overall mean of its
            sample as a whole; and
        (b) its deviation from its own sample mean.

    If the variability within each sample is removed,
each individual score within a sample would be equal
to the sample mean, e.g.:

 5     10    3     *
 5     10    3     *
 5     10    3     *
 5     10    3     *
 5     10    3     *
*****************************************
 5     10    3     *             6    (Overall mean)
(Sample means)

    Thus, ignoring variability within the sample, the
deviation of each individual within its sample, from
the overall mean, is:


   -1     4    -3
   -1     4    -3
   -1     4    -3
   -1     4    -3
   -1     4    -3
```

The squares of these deviations is:

1	16	9
1	16	9
1	16	9
1	16	9
1	16	9

And the 'Sum of Squares BETWEEN groups' is 130 ***

The deviations of individual scores from their own sample means can then be computed. for example, the first score in the first sample is 3 .
This is -2 from the sample mean of 5
The first score in the second sample, 3 is -7 from the sample mean 10 etc.

So, the 'residual' deviations are:

-2	-7	-3
-4	15	7
-2	-7	-3
9	-2	-1
-1	1	0

and the squares of these residual deviations, are:

4	49	9
16	225	49
4	49	9
81	4	1
1	1	0

The sum of the squares of these residual deviations, or the'Combined WITHIN-Groups Sum of Squares' is 502 ***
502
So, the total sum of squares is 632 ,
the BETWEEN groups sum of squares is 130 and the combined WITHIN groups sum of squares is 502 .

632 = 130 + 502 i.e.
The TOTAL sum of squares is equal to the sum of the 'between' groups' sum of squares and the 'within' groups sums of squares.

Total sum of squares (i.e. of individual deviations from the overall mean) can always be analyzed into components, and this is the phenomenon that allows the significance of data to be examined by the powerful ANALYSIS OF VARIANCE, sometimes referred to as ANOVA.

The VARIANCE of the population may be estimated by dividing the 'sum of squares' by the number of 'degrees of freedom' on which the estimate is based. The degrees of freedom are essentially one fewer than the number of scores in the particular sample or sub-sample. For example, in the present case, the total number of scores is 15 .
So, the 'TOTAL d.f.' are 14 . The number of groups is 3 , so the 'BETWEEN GROUPS d.f' is 2 .
There are 5 scores in each of the groups, i.e. 4 d.f. in each of 3 groups, or 12 'WITHIN GROUPS d.f.'

The estimate of population variance from the 'between groups sum of squares is therefore 130 divided by 2
i.e. 65
The estimate of population variance from the 'within groups sums of squares is 502 divided by 12
i.e. 41.8333

If the samples have been randomly drawn from the parent population, it would be reasonable to expect the two estimates to be approximately equal. If the estimate derived from the 'between sum of squares' is much greater than that from the 'within sums of squares', then it would be reasonable to conclude that the two samples were not randomly drawn, but that there is 'a significant difference' between them.

The ratio of 'between-variance' to 'within-variance' (or 'error variance') is called the 'F-ratio' and the significance of the size of the F-ratio can be evaluated from tables.
In the present case, the F-ratio is 65 divided by 41.8333
i.e. 1.55378 for 2 / 12 d.f.

You should now revert to program 888/03 and use the 'ANOVA option'. This will enable you to see the F-ratios from a number of different analyses, and to see how a high F-ratio relates to a large discrepancy between sample means. It will probably be easier to follow if you confine the analyses to comparisons of 2 samples at a time. Also, it will be quicker if you do not ask for printouts of scores or histograms, but for sample statistics only. i.e. when asked what options you want, type NNNNY

DONE